Rainwater… the good, the bad,

- **Given current climate predictions that support increasing and more severe weather events, dense urban built environments are facing increasing challenges surrounding the management of stormwater run-off. Designers and engineers face two scenarios: the existing built environment and the development of new water-centric cities complete with Smart technology.**

And the ugly

Wherever these events occur – city or suburb, residents are asking why? Why isn't there a better solution?

In fact, these are global issues affecting human health and well-being. These severe wet events are creating societal change…some positive, some negative.

BBC.UK.CO

We’re all in the same boat

- Increasing populations
- Unfettered expansion of urbanism
- Depletion of natural resources
- Depletion of productivity

Photo credit: CC BY-SA

Green Stormwater Infrastructure: Reinventing the use of trees in the built environment

Presented by:

Mary Ann Uhlmann,

Urban Horticulture Consulting

Presented to the Georgia Tree Council

Tuesday, August 26, 2019

The simple truth:

Wherever a tree lives, it’s managing rainwater. Trees syphon rainwater from the surrounding soil and hold rainwater in their canopies.

In the built environment, rainwater becomes problematic stormwater due to vast and increasing amounts of impervious surfaces.

Conservation of financial and natural resources, shift the burden of stormwater management and create a more resilient future

How do we integrate green infrastructure design that supports healthy trees and forests into the built environment to manage and treat water where it falls?

Successful incorporation of trees starts with understanding the playing field

The built urban/suburban environment vs…

Expansion and new development

While playing by the rules

- Meet and exceed EPA non-point source pollution remediation compliance for volumetric and water quality tolerances

Trees as a solution set of integrated stormwater management

- Trees are the backbone of high performance green stormwater infrastructure. Only trees can intercept large quantities of water in their canopies while constantly exchanging water through root systems, leaf stomata and the process of photosynthesis. Healthy root zones – the rhizosphere- are often not given enough credit for their immense contribution to hydrological cycling and water quality.

How do trees fit into a GSI project?

- Bioswales
- Bioretention areas
- Rain gardens
- Stormwater planters
- Vegetated green roofs
- Green streets
- Stormwater trenches

Green Infrastructure: Nature-based Solutions for SWM

- It’s biomimicry
  - Replicating the performance of ecological systems that cycle large volumes of water
  - Harnessing the power of plants and soil
    - Using carefully selected plant palettes taking advantage of evolved morphological and physiological features adapted to extreme conditions
    - Developing and using growing media blends that promote development of a functioning rhizosphere resulting in optimal retention/flow/detention and biological treatment of run-off

Objectives

Create regenerative integrated stormwater management systems

- Reverse the percentage of impervious surfaces
- Keep and process stormwater on the site
- Create, enhance and/or restore ecosystem services to urban environments
- Engender stewardship of natural resources
- Improve stormwater quality and decrease dependence on gray infrastructure

Trees meet these objectives and more

Create regenerative integrated stormwater management systems

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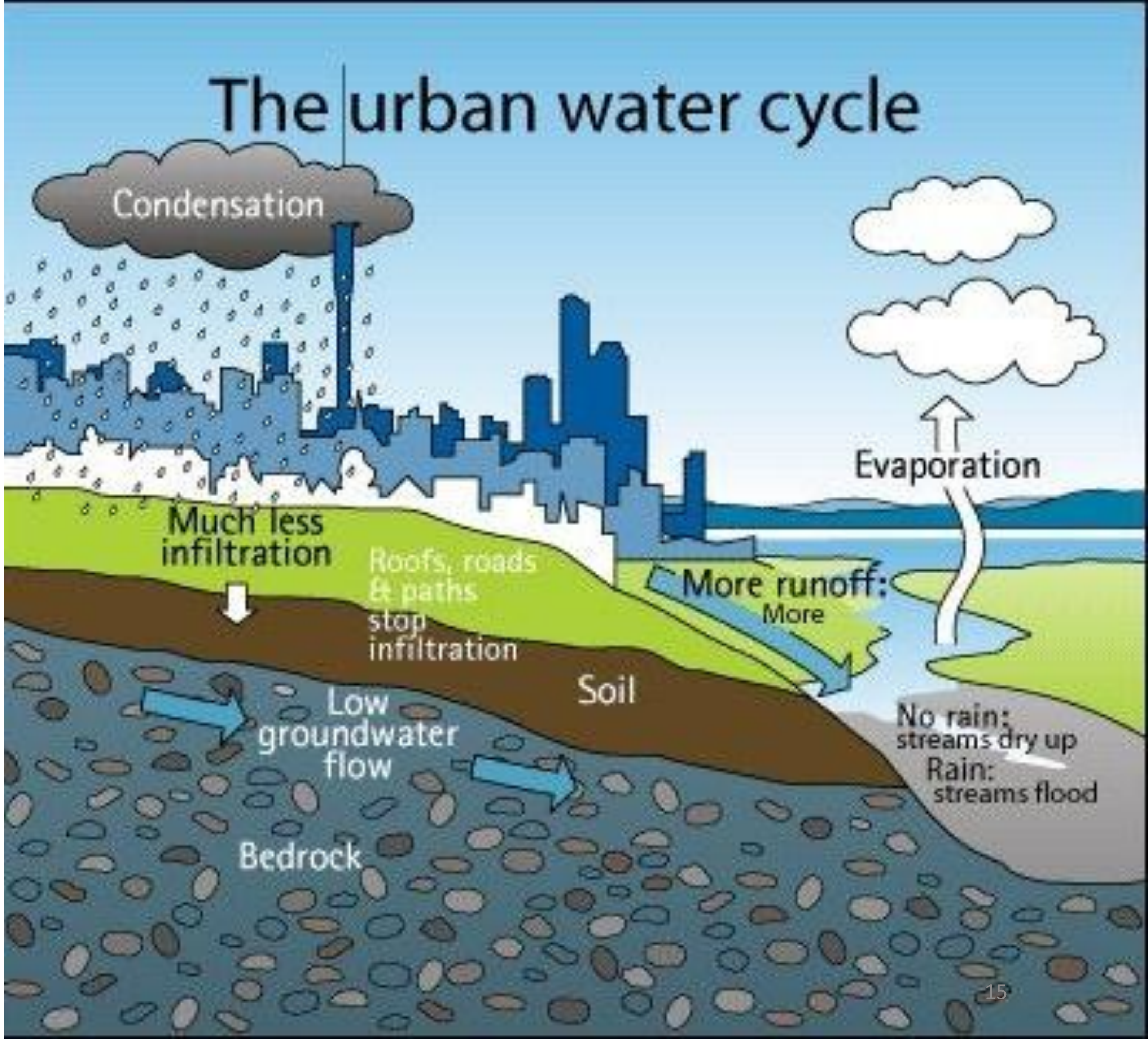
The other green $$$ benefits of trees in GSI

Year Completed	i-Tree Reference City	Number of Trees Studied	Annual Stormwater Benefits (dollars)	Rainfall Intercepted Annually by Trees (million gallons)
2006	Albuquerque, N.M.	4,586	$55,833	11.1
2005	Berkeley, Calif.	36,485	$215,645	53.9
2004	Bismarck, N.D.	17,821	$496,227	7.1
2007	Boise, Idaho	23,262	$96,238	19.2
2005	Boulder, Colo.	25,281	$357,255	44.9
2006	Charleston, S.C.	15,244	$171,406	28.3
2005	Charlotte, N.C.	85,146	$2,077,393	209.5
2004	Cheyenne, Wyo.	17,010	$55,301	5.7
2003	Fort Collins, Colo.	31,000	$403,597	37.4
2005	Glendale, Ariz.	21,480	$18,198	1.0
2007	Honolulu, Hawaii	235,800	$350,104	35.0
2008	Indianapolis, Ind.	117,525	$1,977,467	318.9
2005	Minneapolis, Minn.	198,633	$9,071,809	334.8
2007	New York City, N.Y.	592,130	$35,628,220	890.6
2009	Orlando, Fla.	68,211	$539,151	283.7
2003	San Francisco, Calif.	2,625	$466,554	99.2
2001	Santa Monica, Calif.	29,229	$110,784	3.2

i-Tree.org

Challenges: Understanding the manmade watershed within a watershed

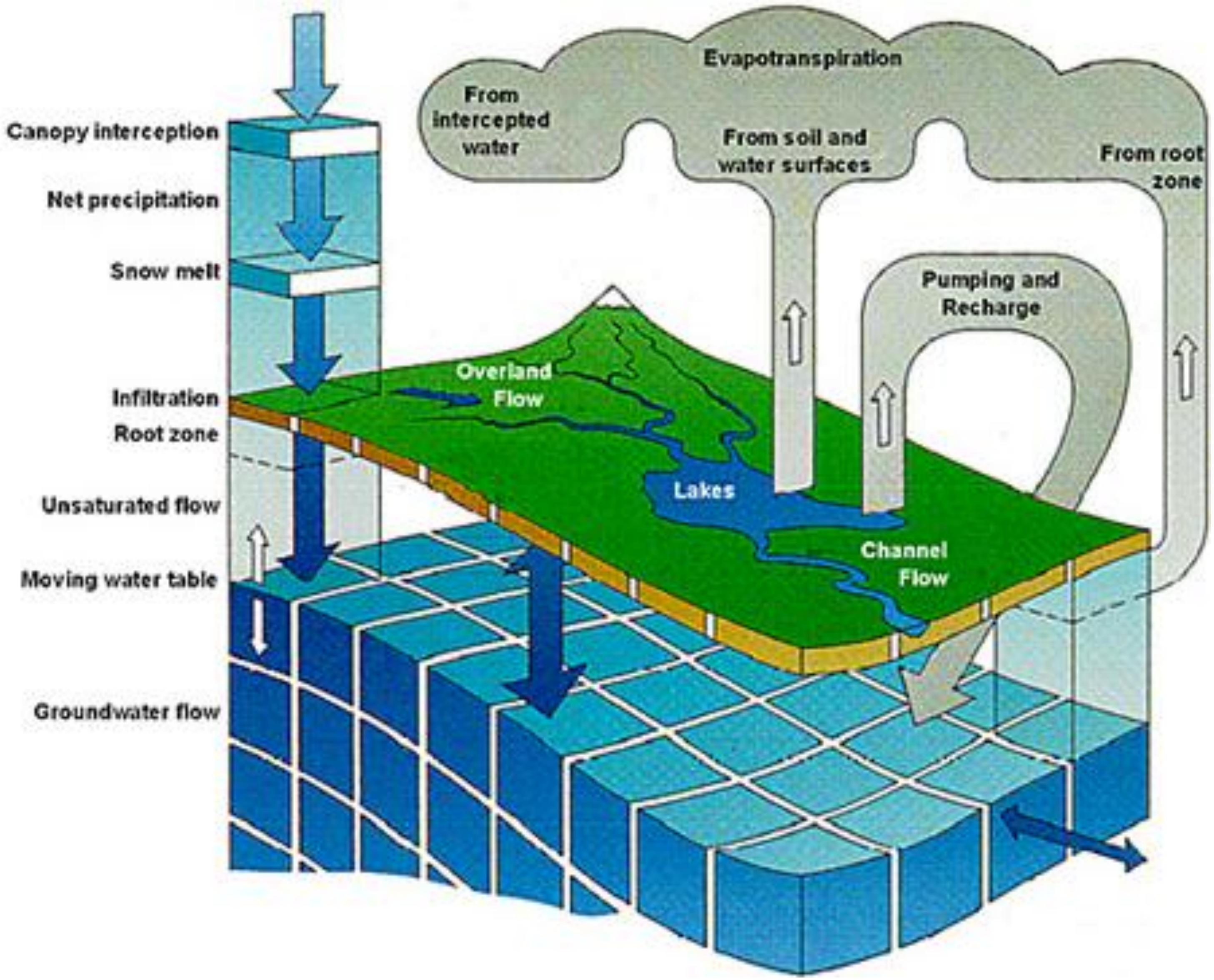
The <u>built urban watershed </u>evolves from a manmade confluence of impervious surfaces equal to many times the original property footprint.



nationalgeographic.com

Justification for use

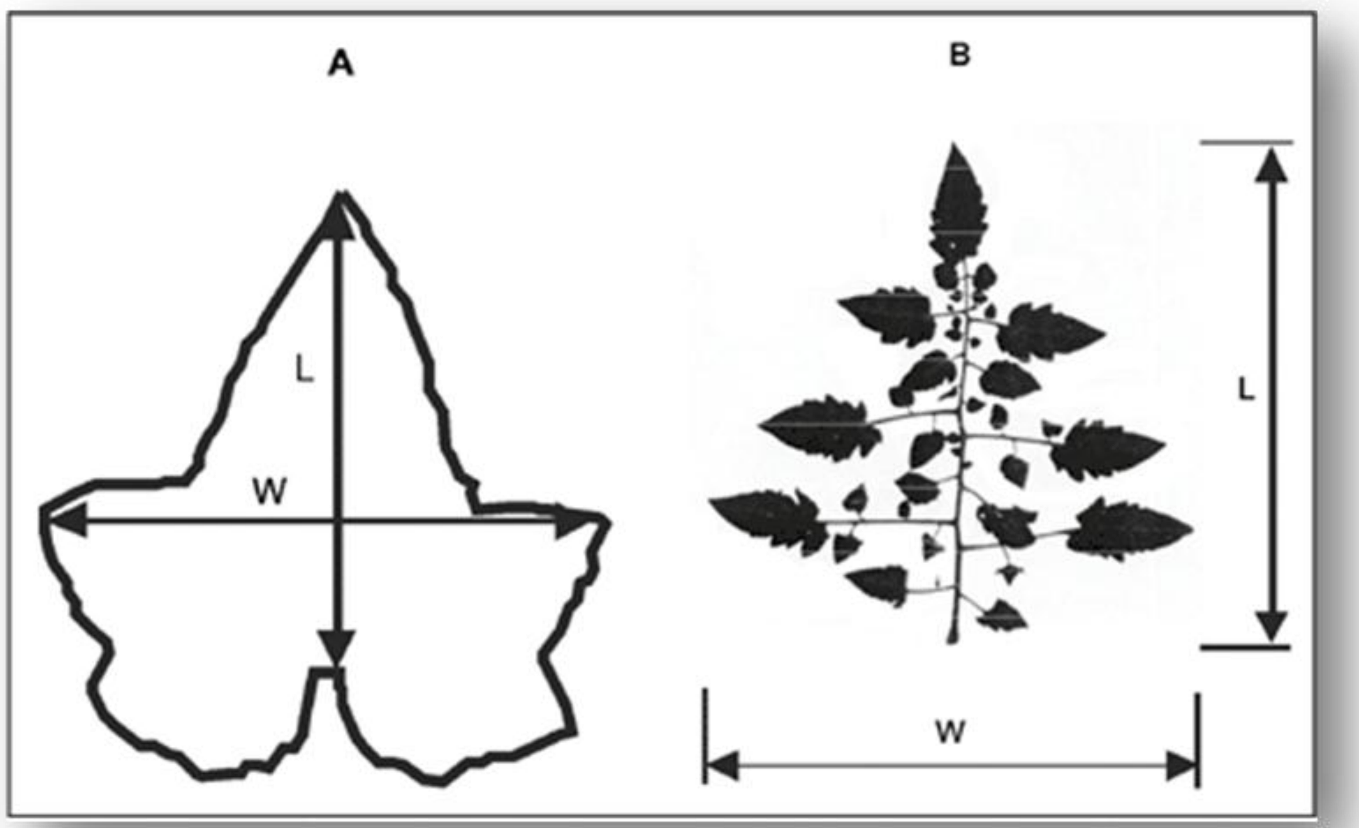
- Until recently, engineers and urban planners lacked the tools necessary to model the complicated hydrological functioning of trees and other vegetation in stormwater BMPs. Now, sophisticated modeling tools are available to create integrated hydro-ecological models that deliver a framework from which the effectiveness of trees and other vegetation can be quantified. This is key to the future use of trees in green infrastructure.



Challenge: Scale

In order to make reasonable, quantifiable improvements to any municipality or water utility's stormwater management efforts, a large footprint is necessary. In dense urban environments, where do we create scale?

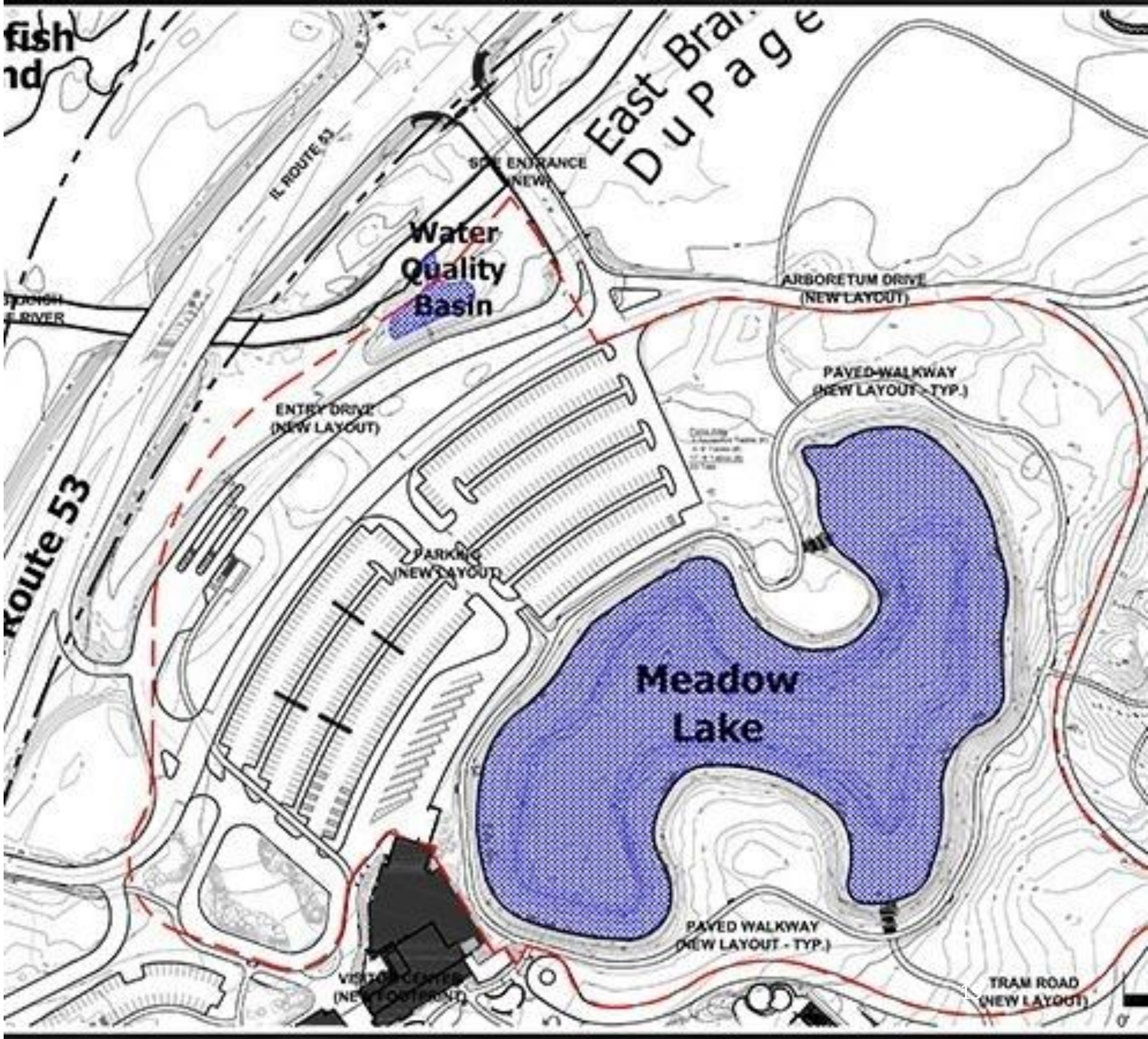
Hong Kong, Photo credit: hellorakas.com



Trees provide enormous surface area

The Morton Arboretum, Lisle, IL

- The goal: reduce the volume and quality of run-off from parking lot into Meadow Lake
- Answer: green infrastructure
  - Permeable pavers
  - Bioswales



Trees	
Botanical Name	**Common Name**
Acer campestre	HEDGE MAPLE
Acer miyabei 'Morton'	STATE STREET ® MIYABE MAPLE
Acer x freemanii 'Autumn Blaze'	AUTUMN BLAZE FREEMAN'S MAPLE
Acer x freemanii 'Marmo'	MARMO FREEMAN'S MAPLE
Celtis occidentalis	HACKBERRY
Cercis canadensis	REDBUD
Corylus colurna	TURKISH HAZELNUT
Fraxinus americana 'Autumn Purple'	AUTUMN PURPLE WHITE ASH
Ginkgo biloba	GINKGO
Gymnocladus dioicus	KENTUCKY COFFEETREE
Juniperus chinensis 'Fairview'	FAIRVIEW CHINESE JUNIPER
Malus 'Adams'	ADAMS CRABAPPLE
Malus x zumi 'Calocarpa'	REDBUD CRABAPPLE
Ostrya virginiana	IRONWOOD
Quercus bicolor	SWAMP WHITE OAK
Quercus macrocarpa	BUR OAK
Syringa pekinensis 'Morton'	CHINA SNOW ® PEKING LILAC
Syringa reticulata	TREE LILAC
Taxodium distichum	BALD-CYPRESS
Tilia tomentosa 'Sterling'	STERLING SILVER ™ SILVER LINDEN
Ulmus 'Morton Glossy'	TRIUMPH ™ ELM

Tree performance within the Water Budget

Typical water inputs from impervious surfaces

- Precipitation
- Irrigation
- Mechanical
  - HVAC
  - Condensation

Typical water outputs from trees

- Transpiration
- Soil storage
- Discharge
- Unmeasured stock (shrubs and other vegetation)

Credit: P.B. May, P. Breen, L. Denman (2006) An Investigation of the Potential to Use Street Trees in Bioswales

Green parking retrofit

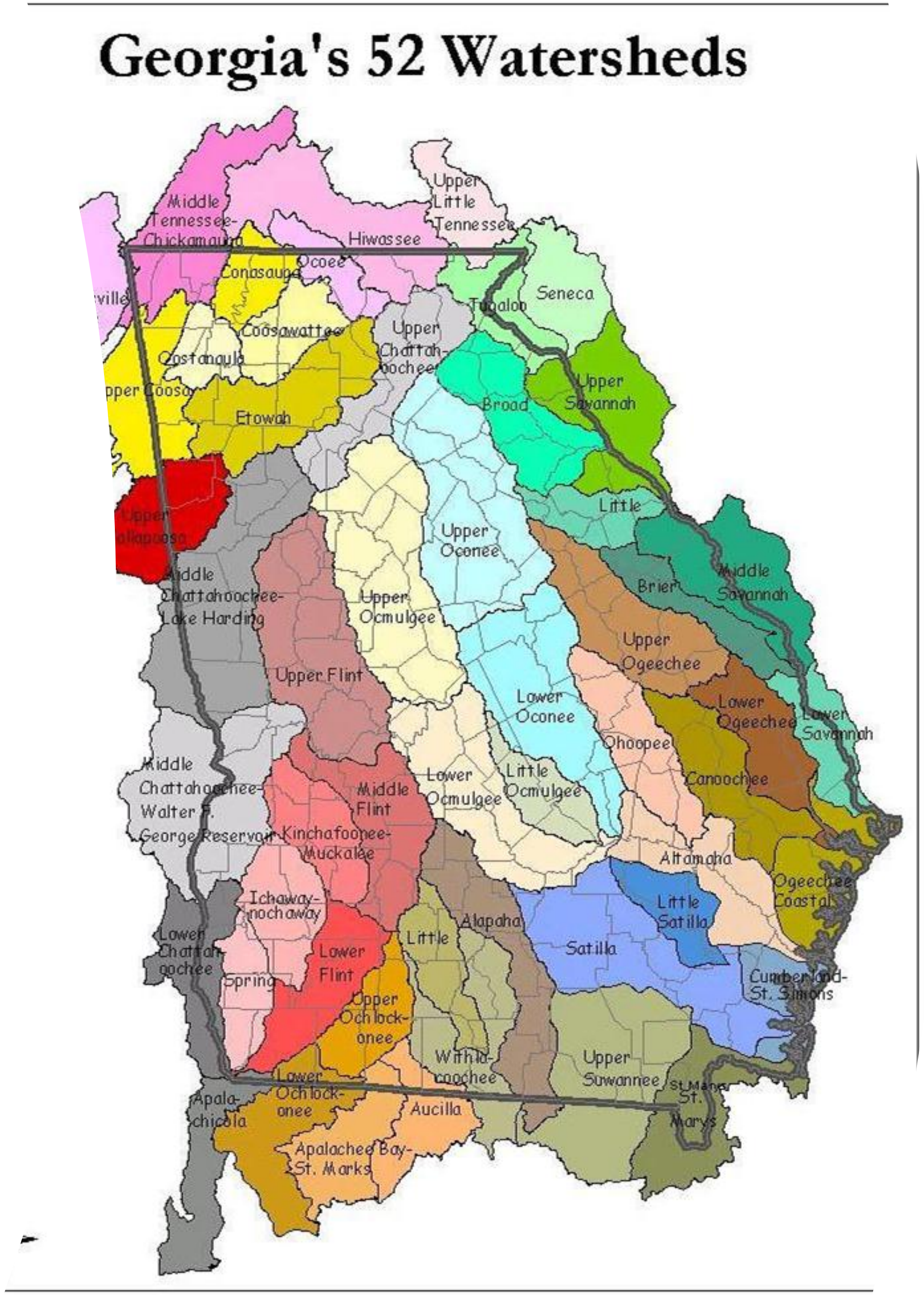
Water subtraction results

- Tree transpiration accounted for 46 – 72% of all water inputs
- Difference in tree species
  - Rate of stomatal conductance
  - Total leaf are index
  - Health and condition of tree
- Quercus macrocarpa was most efficient in water budget subtraction/extraction

Surround and envelop existing urban areas and appropriate structures in layers of green infrastructure which serves holistically as a first line of defense, improving both the resilience and performance of the existing grey infrastructure.

The Retrofitted Water-centric City Theory

Start with the watershed



- We repair as much damage as we can through restoration efforts
  - Urban forest restoration
  - Stream restoration
  - Daylighting streams in urban areas

Daylighting Tributary Streams: Headwaters at Tryon Creek

- First daylighted creek in Portland, OR
- Runs length of 2.8-acre property
- Connects an upstream, forested wetland to a downstream rain garden
- Tree selection reflects existing native trees in forested wetland
  - Pacific crabapple
  - Ash
  - Alder
- Native vegetation restores natural hydrologic function

Green Streets

- A new twist to the all-American tree-lined street
  - Rain gardens and bioretention
  - Tree box filters
  - Pervious sidewalks
  - Curb extensions
  - Swales

Street tree applications for GSI

- Dr. Sasha W. Eisenman, Temple University, Dept of Landscape Architecture and Horticulture
  - Research to study the effectiveness of trees in GI stormwater trenches
  - Of 24 species studied, performance varied widely
  - Platanus x acerifolia Bloodgood and Acer rubrum 'Armstrong' made highest contribution to GI SWM
  - In addition, Koelreuteria paniculata and Prunus sargentii proved to grow faster and provide higher rates of stomatal conductance when planted in well designed stormwater trench as opposed to same species in isolated tree pits

Credit: Sasha W. Eisenman, Ph.D., Water relations of trees growing in GI stormwater trenches

Retrofitting existing BMPs to include native vegetation

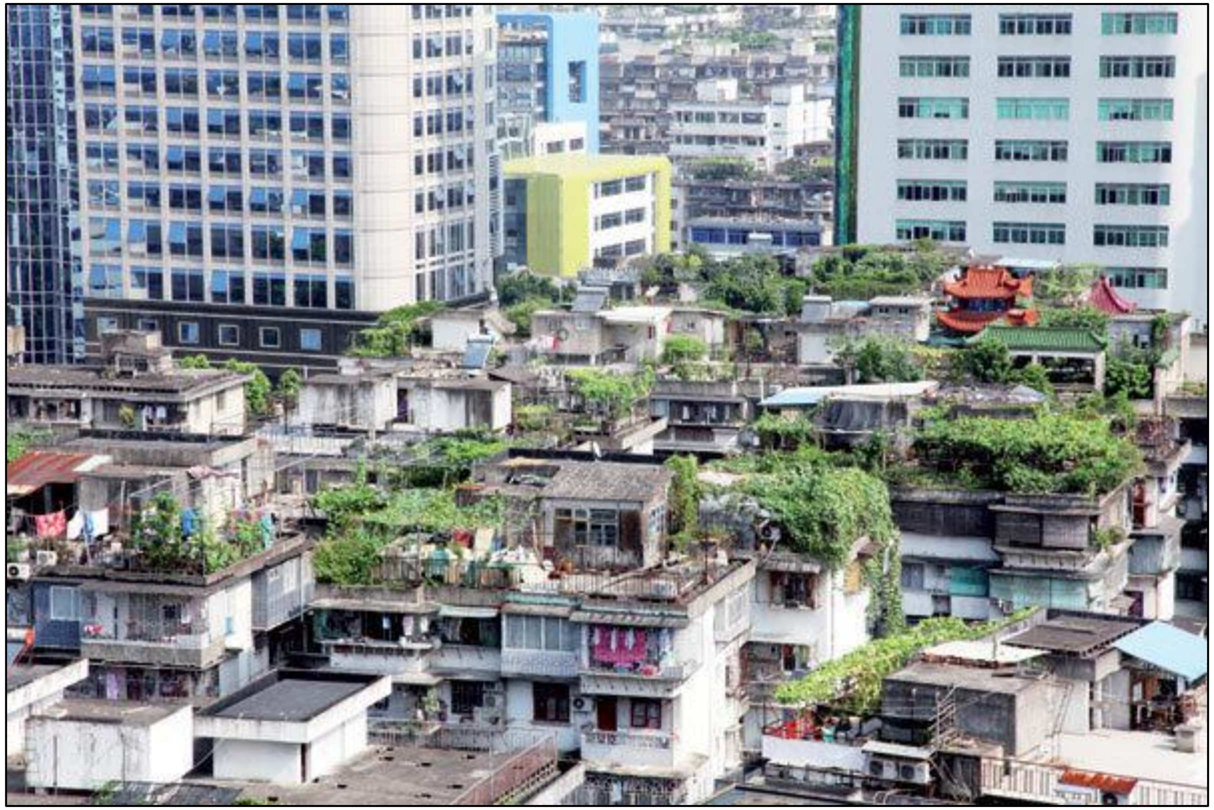
- Convert a conventional detention basin into a Vegetated Water Quality Basin
  - (1) maximize the flow path through the basin
  - (2) slow the flow of stormwater through the basin
  - (3) improve how plants use stormwater to increase absorption and evapotranspiration
  - (4) filter and trap common runoff pollutants
  - (5) promote soil saturation/groundwater recharge
  - (6) increase evaporation of stormwater

Even in a dense urban environment

Cheng-du campus, Cheng-du, China

Stormwater soaks into the vegetated depressions and is purified as it filters through a rich and vibrant rhizosphere.

Sponge City Design, China



By 2020, the government wants 20% of the built area of each pilot district to have sponge city functions, meaning at least 70% of stormwater runoff should be captured, reused, or absorbed by the ground. By 2030, a huge 80% of each city should meet this requirement.

Sponge City Goals

- Adapt ‘flexibly’ to changes in the environment
- Reduced disturbance and damage to the natural world
- Resolve urban water shortage problems
- Enable natural storage, natural permeation and natural purification
- Provide some means for management of manmade environmental damage
  - Heat island effect
  - Air and water pollution
  - Human health and well-being

Sponge City Concepts: Yanxiu Park, Liaoning, China

Prior to development


A tree-human-water interface

But what about the existing built environment?

Sponge City technology is China’s experiment in LID for expansion of or development of new cities.

Can we retrofit our buildings to create water-centric building envelopes?

Can we re-appropriate unused assets to develop new green opportunities for stormwater management?

The Water-Centric High-Performance Building Envelope

- Building envelopes equate to enormous underused assets and resources for SWM
- Accumulated surface area of all ‘5 sides’ of a building are put to work
  - Green Roofs
  - Blue Roofs
  - Green canopy roofs
  - Living walls
  - Stormwater planters/balconies
  - Rainwater capture

The Vertical Forest: Bosco Verticale in Milan, Italy

- Cloaked in forested balconies, Bosco Verticale designed by Stephano Boeri Achitetti is setting the standard for Vertical Forest Builings.

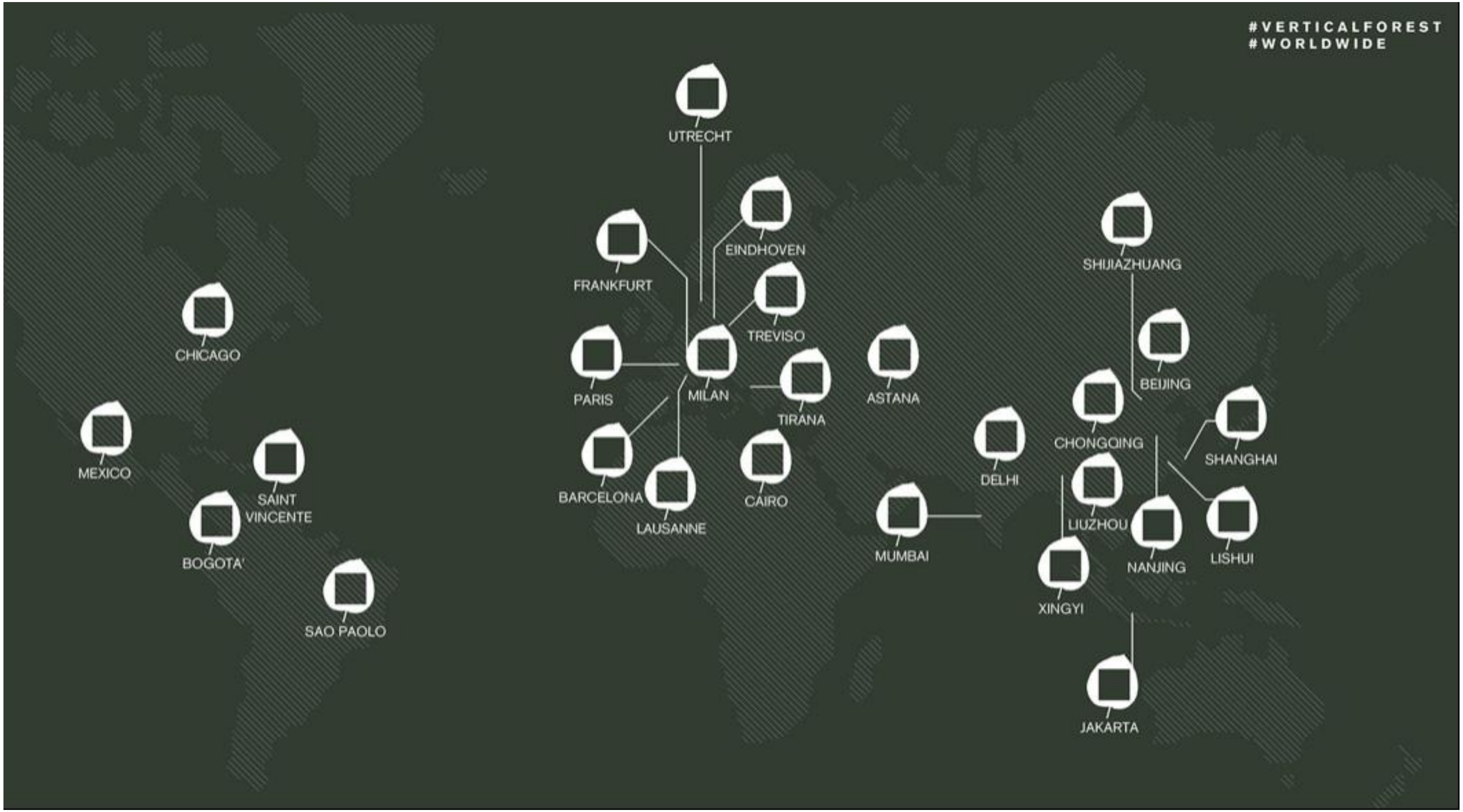
Where’s the stormwater?

Over 900 trees, 4,500 bushes and 15,000 plants envelope the twin towers in vegetation creating an evaporative value equivalent to a mature 5-acre forest. Rain that would otherwise run from the roof to the stormwater system below is captured and re-used for irrigation. Rain that hits the building walls is captured in the foliage and growing media.

Vertical ForestING Benefits

"Like the trunk of a tree, its outer shell turns it into a living urban archive, a witness to the slow and gradual growth of a new and rich urban ecosystem in the heart of the city"

- Urban buildings that are completely covered by the leaves of trees and plants create new urban ecosystems
- Equivalent 1,000 m2 of forest = 100 m2 of vertical forest
- 2 trees, 8 shrubs and 40 bushes dedicated to each human living in the building
- The building's green vegetation filter reduces air pollution


#VERTICALFOREST
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CAIRO
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SAO PAOLO
MUMBAI
DELHI
SHIJIAZHUANG
BEIJING
CHONGQING
SHANGHAI
LIUZHOU
NANJING
LISHUI
XINGYI
JAKARTA

The Forest City Concept

Liuzhou Forest City Concept

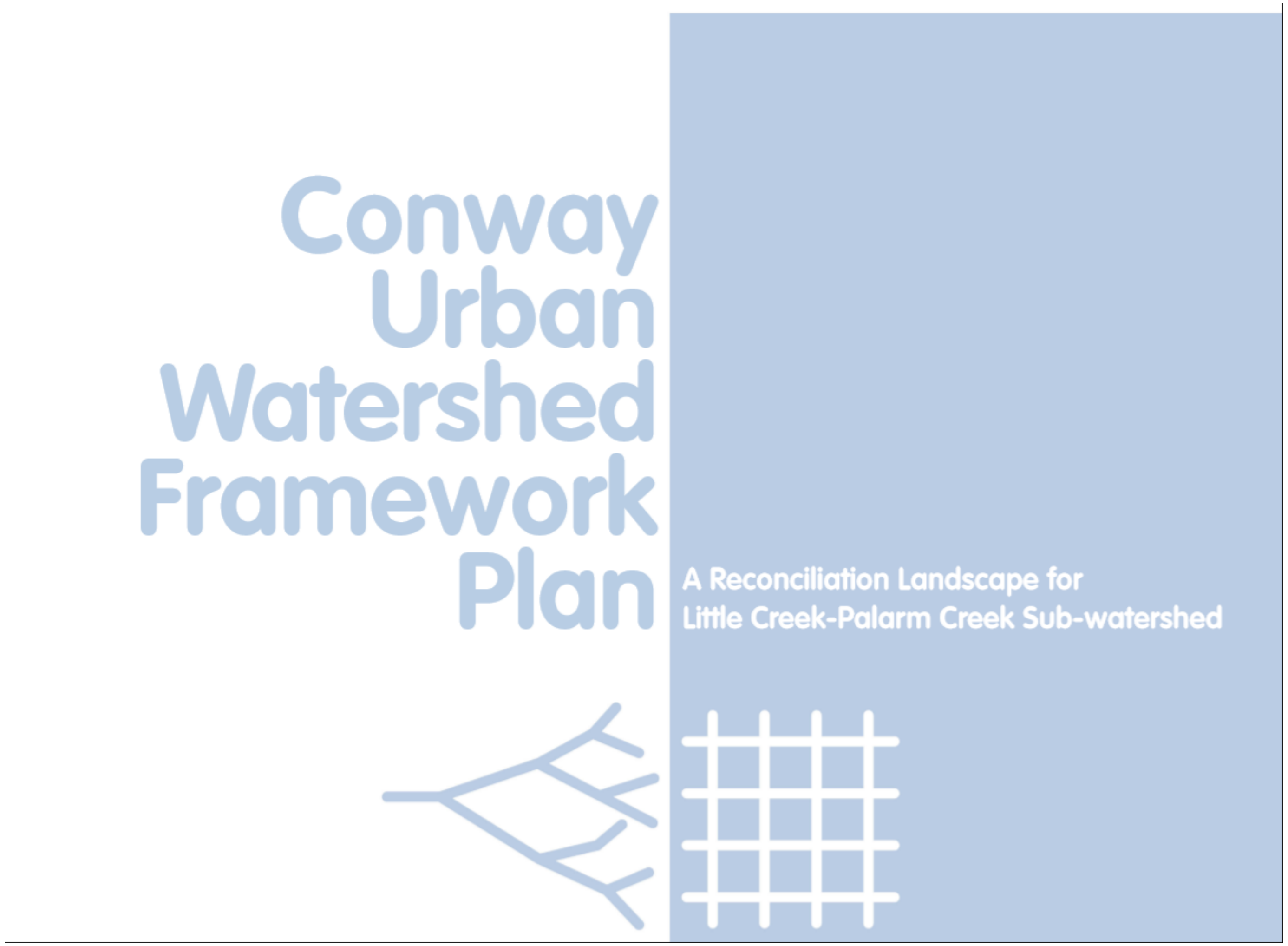
By the numbers

1 million plants of more than 100 species

40,000 trees that together absorb almost 10,000 tons of carbon dioxide and 57 tons of pollutants and produce approximately 900 tons of oxygen annually.

Forest City will help to decrease the average air temperature, improve local air quality, create noise barriers, generate habitats, and improve local biodiversity in the region.

Changing the dialogue: Think of GSI as a reconciliation landscape



Conway, AK Watershed Plan

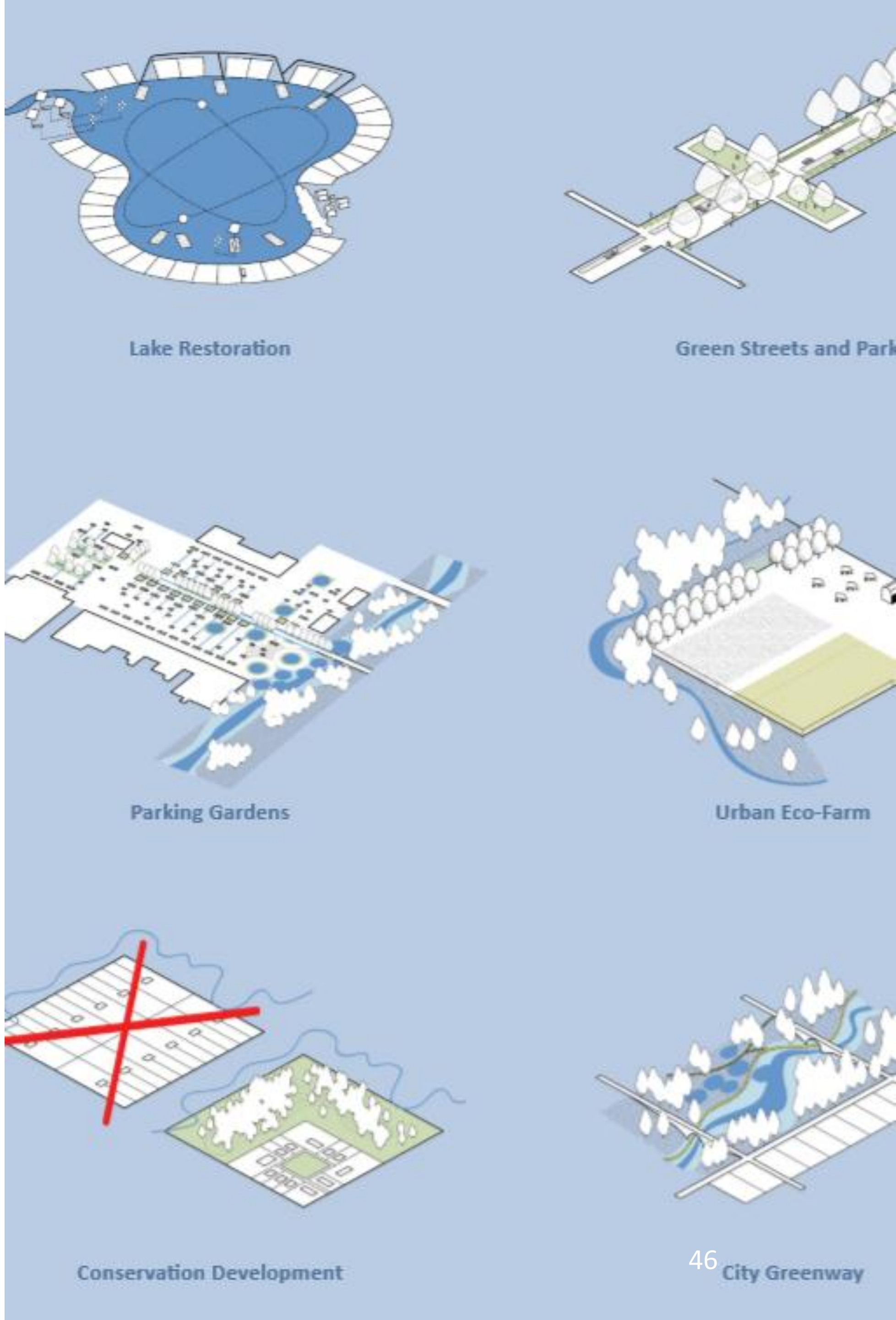
“Where two distinct types of network meet, flow slows down to diffusion. This is where the network structure is most vulnerable—and interestingly where living processes occur.”

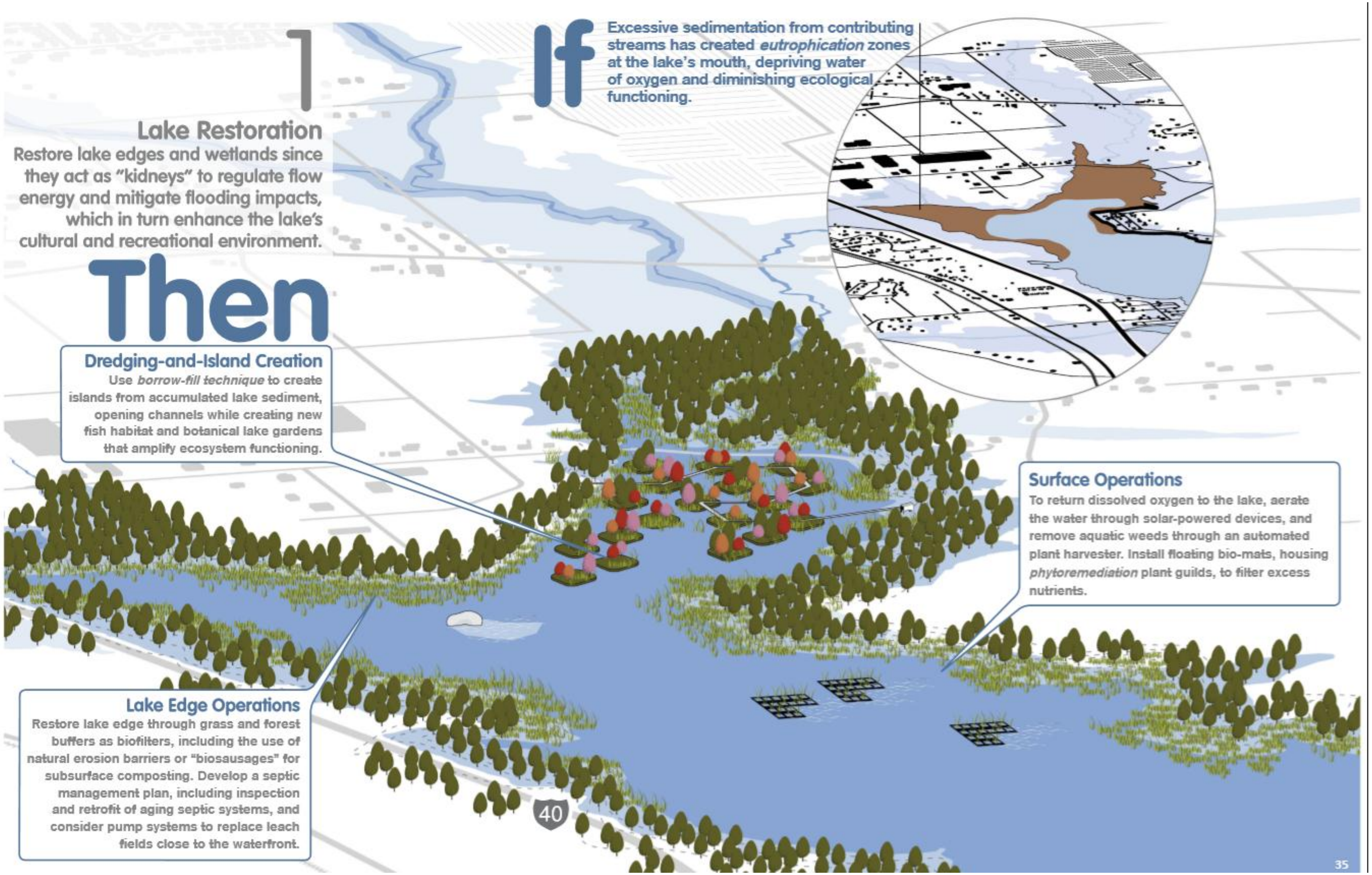
Design for a Living Planet: Settlement, Science, and the Human Future Michael Mehaffy and Nikos Salingaro

The City and the Watershed: A Reconciliation Landscape How can city form fix the watershed? The city and the watershed are distinct systems of flow that generate shape and structure across the landscape to maximize their intrinsic objectives.

Value-added infrastructure retrofits

- The city can be engineered to work like a sponge with vegetation – trees, shrubs, grasses and forbs – working within their natural capacity and enhanced with engineered solutions.

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Lake Restoration
Restore lake edges and wetlands since they act as "kidneys" to regulate flow energy and mitigate flooding impacts, which in turn enhance the lake's cultural and recreational environment.
If
Excessive sedimentation from contributing streams has created *eutrophication* zones at the lake's mouth, depriving water of oxygen and diminishing ecological functioning.
Then
Dredging-and-Island Creation
Use *borrow-fill technique* to create islands from accumulated lake sediment, opening channels while creating new fish habitat and botanical lake gardens that amplify ecosystem functioning.
Surface Operations
To return dissolved oxygen to the lake, aerate the water through solar-powered devices, and remove aquatic weeds through an automated plant harvester. Install floating bio-mats, housing *phytoremediation* plant guilds, to filter excess nutrients.
Lake Edge Operations
Restore lake edge through grass and forest buffers as biofilters, including the use of natural erosion barriers or "biosausages" for subsurface composting. Develop a septic management plan, including inspection and retrofit of aging septic systems, and consider pump systems to replace leach fields close to the waterfront.
40
35

2A

Green Streets and Parks: Markham Town Square

Wetland Town Square ❶
Reformat the conventional town square to become both urban park and water treatment facility.

Rain Gardens ❷
Use small bioswales designed to manage stormwater runoff by filtering sediment and pollutants.

Bio-Retention Mat ❸
Incorporate a wetland landscape designed to manage stormwater runoff, mostly through retention.

Green Street ❹
Build streets with low impact development facilities, to treat stormwater runoff, provide shade and habitat, and to purify air.

Evapotranspiring Tree Bosques ❺
Employ groves of deep-rooting trees to uptake large amounts of water for transpiration.

Living Bridge ❻
Use vegetated bridges with phytoremediating and flowering plants, allowing pedestrian access to mounds as well as providing ecosystem services.

Multi-programmatic Mounds (Pumping Water, Recreational, Habitat) ❼
Design vegetated mounds as green spaces for recreational activities while absorbing and transpiring stormwater runoff through tree bosques.

0 60' 120'


2A
Green Streets and Parks:
Markham Town Square
Phreatophytic Bosques
are water-loving, deep-rooted trees (e.g., Cottonwoods, Poplars, Willows, etc.) that provide flow **regulating services** by pumping, storing, and evapotranspiring groundwater where a high water table limits runoff retention. An acre of these trees can pump more than a million gallons of water annually.
Underground Filtration Basins
are rock-filled trenches with bio-films beneath porous pavement that filter sediment and infiltrate stormwater runoff providing water **regulating services** in streets.

Nature is our biggest ally

When it comes to tackling some of the world’s biggest challenges, nature can be one of our strongest allies.

Integrating nature into mainstream infrastructure systems can produce lower cost and more resilient services.

- -March 2019

Currently, we have islands of effort

- While enormous strides have been taken, next steps lie in the design of retrofitting our cities to use effective GI treatment trains combining green infrastructure with gray to create effective and quantifiable stormwater management systems. Like the Sponge City concept, this will create connected tree filled corridors of nature-based stormwater solutions.

- We can build these now.
- We can do it at the scale necessary.

McCormick Center, Chicago

Thank you!

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